PATENT SPECIFICATION 1,179,172

DRAWINGS ATTACHED.

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1,179,172

Date of Application (No. 1286/67) and filing Complete Specification: 10 Jan., 1967.

Complete Specification Published: 28 Jan., 1970.

Index at acceptance:—**B5** B(1R1, 20C, 21B, 24C3, 26A1); **G1** A(24Y, 26Y, 261, 263, 265, 316, 35Y, 36Y, 361, 363, 365, 402, 407, 42Y, 422, 423, 426, 428, 43Y, 432, 433, 436, 438, 44Y, 45Y, 46Y, 461, 463, 467, 478, 489, 506, 681, 761).

International Classification:—**B 29 d 23/04.**

COMPLETE SPECIFICATION.

Method and Apparatus for Measuring the Thickness of Sheet Material.

We, INDUSTRIAL NUCLEONICS CORPORATION, a corporation incorporated in 1969 and existing under the laws of the State of Ohio, United States of America, of 650 Ackerman Road, Columbus, Ohio, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates generally to a method and apparatus for measuring the thickness of a sheet of material produced by a tubular product forming device, such as a blown film extruder, the tubular product being flattened to form a sheet of double thickness.

The plastics industry has used many types of extruders to obtain a sheet of material. In most of these extruders, material to be formed is dumped into a hopper and heated in the extruder until it becomes deformable. A motor driven screw forces the material through a die. After leaving the die the material cools and hardens in the air and a take-away conveyor mechanism removes the formed material.

There seem to be two principal methods used to provide an output in sheet form. One method is to use a flat die having a plurality of adjustable die bolts spaced in line across the width of the sheet emerging from the die orifice. The other is to use an annular die with adjustable die bolts mounted on the periphery and extending radially from the core around the circular orifice. Air is forced through the center of the die to blow the extruded plastics into a thin walled bubble. Pinch rolls flatten the bubble into a sheet of double thickness after which it is slit to provide a wide sheet of the required thickness. To eliminate heavy or light streaks from the produced sheet it has been found expedient to rotate the die, the bubble, or, in some cases, even the extruder. If one or more die bolts are maladjusted, the strips or zones of objectionable thickness spiral around the circumference of the bubble and do not cause a pile-up of material at any particular spot on the windup roll.

It is of economic importance to produce a sheet having a uniform desired thickness. In systems using the linear die technique it has been proposed to use a scanning radiation gauge to measure cross-sheet thickness and exert control on screw speed and take-away speed in accordance with said thickness information. This approach is impractical in the rotating extrusion process described above because scanning yields only a combined double thickness profile. It is conceivable that a high and a low spot may coincide to produce a double thickness that is twice the desired thickness.

According to the present invention, therefore, we provide a method of measuring the thickness of a sheet during production by a tubular product forming device which distributes variations in thickness about the circumference of the tubular product, the tubular product then being flattened to form a moving sheet of double thickness, said method comprising the steps of measuring the thickness of the double sheet along one edge thereof and deriving from the measurements an indication of a single thickness across the sheet.

There is further provided in apparatus for producing sheet material comprising a tubular product forming device which produces variations in thickness which are distributed about the circumference of the product and means for flattening the product to form a sheet of double thickness, a measuring system comprising means positioned at one edge of the sheet for measuring the total sheet thickness at said edge and means for deriving from said measurements an indication of the single thickness across said sheet.

We also provide in apparatus for producing plastic sheet material comprising a tubular product forming device including an extruder having a generally circular die comprising a plurality of adjustable die sections spaced therearound, means in said circular die for receiving raw plastics material at an adjustable rate under pressure and extruding a continuous generally tubular length of said plastics material, means for blowing air through said circular die to expand said tubular length of plastics material into a bubble, means for rotating at least one component of said extruder to distribute thickness variations in said plastics material about the circumference of the tubular length thereof, and means for flattening said bubble of plastic material into a sheet of double thickness, the output of each adjustable die section forming a longitudinally extending spiralling zone with each zone overlapping itself at the edges of the flattened sheet to form individual double thickness areas which pass a predetermined fixed position adjacent one edge of the sheet as the sheet is extruded, a measuring system as defined in the previous paragraph in which said measuring means includes a gauge overlying said predetermined fixed position and immediately adjacent said one edge of said flattened double thickness sheet for measuring the double thickness dimension thereof and means for averaging the output of said gauge for a time period sufficient to include the thickness variations produced over at least one rotation of the rotating means and in which said deriving means includes means for displaying said average value of the thickness dimension of said double thickness sheet at said edge as an indication of the average value of the single thickness profile of said sheet to enable adjustments to be made in the average sheet thickness produced by said extruder.

In accordance with a preferred embodiment of the present invention, a thickness measurement is performed at the edge of the flattened bubble produced by the blown film extruder having a rotatable die comprising a plurality of adjustable die sections about the periphery thereof. While the thickness profile is actually a double one, by virtue of the location of the point of measurement, it is taken substantially at a single point, i.e. the thickness thereat is determined by only one peripheral die section, and the true sheet thickness is exactly half of the measured value. As the die element rotates it will thus be clear that over the period of a complete rotation, the true double thickness output of each adjustable peripheral die section in succession will be obtainable. The measured profile is averaged over a period of time equal to the time for one rotation of the die. Both the measured profile and the time average values are read out on a chart recorder in a convenient form easily interpreted by operating personnel for facilitating control of the extruder.

The present invention provides a novel method of deriving output information of an extrusion process and presenting said information for use by operating personnel. Other features and advantages of the present invention will become more apparent upon reference to the following description when taken in conjunction with the appended drawings in which:

Fig. 1 is a block diagram showing a plastic extrusion process and a measuring and recording system applied thereto in accordance with the present invention;

Fig. 2 is an enlarged perspective view of a portion of the process shown in Fig. 1 showing radiation gauging apparatus that is of particular utility in this invention;

Fig. 3 is a circuit diagram of the measuring and recording system shown in Fig. 1;

Fig. 4 is a functional circuit diagram of a timing apparatus useful in the system shown in Fig. 1;

Fig. 5 is a block diagram of an alternative embodiment of the present invention which correlates the recorder presentation with the rotation of the die;

Fig. 6 is a top view of the extruder die showing means for actuating the die adjustments; and

Fig. 7 is a view of a preferred circular chart useful in facilitating the die adjustment illustrated in Fig. 6.

With specific reference to Figs. 1 and 2, a portion of a plastics sheet-forming process is illustrated as a particular application of the present invention. An extruder 10 receives raw material in a hopper 12. A motor 14 drives a screw (not shown), forcing the material down the extruder and out of a rotating die member 16 provided on the end of an upturned neck 10a of the extruder. A plurality of adjustable die bolts 17 extend radially from the center of the die 16 and serve to vary the spacing of peripheral die sections from the core of the die. Air from a supply 18 is blown through the center of the die 16 and serves to expand the extruded material into a bubble 20. A series of rolls 22 flatten the upper end of the bubble 20 thereby producing a flat sheet 24 of double thickness.

The doubled sheet is drawn by a pair of take-away pinch rolls 25 and is subsequently slit and collected on windup reels (not shown).

For purposes of inventory and providing an economic operation, it is necessary for operating and plant personnel to know how much the produced sheet varies in thickness. To provide some indication of this variation, a radiation gauge 26 is provided comprising a radiation source 28 and a detector 30. The gauge 26 operates on the principle of radiation absorption in which the detected radiation is a function of absorber thickness. For a more detailed description of the gauge 26, reference may be had to U.S. Patent 2,790,945, The gauge 26 is mounted at the extreme edge of the flattened bubble 24 as it emerges from the pinch rolls 22.

The placement of the gauge 26 and the reasons therefor become apparent upon reference to Fig. 2. Referring briefly to Fig. 2, the gauge 26 comprises a U-bracket 32 having a lower and an upper arm for housing the source and detector elements 28 and 30. The bracket is mounted on a carriage 34 movable along a rail 36 by means of a motor 38. The gauge 26 effectively measures an area 40 which may be circular, ellipsoidal or rectangular depending on the source geometry employed.

The flattened bubble can be pictured as having a plurality of longitudinally spiralling zones, each having a thickness determined by one of the adjustable die sections of the rotatable die 16. The pitch of the spiralling zones depends on both the rotational velocity of the die member 16 and the take-away speed of the conveyor mechanism. It is apparent to those skilled in the art that the measuring area cannot be allowed to extend beyond the edge of the sheet because then some direct radiation from the source will strike the detector. To enable the gauge 26 to see a strip always located on the sheet, a simple edge-sensing device and control may be provided as indicated by the reference numerals 42 and 44. Sheet edge followers are well known to those skilled in the art so no further discussion of unit 42 is presented here. Control unit 44 actuates the drive motor 38 to continuously position the carriage 34 to centre the sheet edge in the air gap of the sensing unit 42.

Referring back to Figure 1, the thickness-representative output of the radiation detector 30 is received by a measuring servo 46. The measuring servo drives a chart recorder 48 which records the profile information as a trace 50a on a moving chart 52. A profile-averaging computer 54 serves to integrate the thickness measurements of the radiation gauge 26. The output of the computer may be read out as a trace 50b following the profile trace 50a. A timer unit 56 determines the period of signal integration performed by the computer 54 which may be set for a duration equivalent to the time required for one revolution of the die 16. A control unit 58 provides the switching functions needed to display the derived process information.

While various circuits may be used to provide the required readout, a particularly useful circuit appears in Fig. 3.

A radioactive source 60 is disposed adjacent the edge of sheet 24 for directing radiant energy toward a detector 62 arranged on the opposite side of said sheet. A conductor 64 serves to deliver generated electrical signals to the measuring servo 46. A computer bridge 70 includes a repeat slidewire potentiometer 72 connected by means of potentiometers 73 and 74 to a target potentiometer 75, a source of bridge potential represented by the battery 76 connected to the adjustable taps of the potentiometers 73 and 74, a recorder slidewire 77, and a pair of potentiometers 78 and 79 serving to connect the recorder slidewire potentiometer 77 to the battery 76. The measuring servo 46 is mechanically coupled to the movable arm 72a of the repeat slidewire as indicated by the dotted line 66. The setting of the tap 75a of the target potentiometer is determined by a target adjust knob 80 which may be provided on the front panel of the recorder 48 for the convenience of operating personnel. A movable target indicator 82 is coupled to the knob 80 by the mechanical linkage indicated at 83. The indicator 82 may be manually positioned across a recorder scale 84 which may be suitably calibrated in units of mils. thickness, for example.

Movable tap 72a of the repeat slidewire is electrically connected via a set of relay contacts 90a to the integrator 54. In a preferred form, integrator 54 comprises a stabilized operational amplifier 92 utilizing an inverse feedback principle, an input resistor 94, a capicitor 96 connected between the input and output terminals of said amplifier, and a resistor 98 adapted to shunt said capacitor when a set of relay contacts 90b are closed.

The adjustable tap 77a of the recorder slidewire is connected to one terminal of a D. C. chopper 100. The integrator 54 may be connected to another terminal of the chopper 100 by a set of relay contacts 90f. In a well-known manner, chopper 100 produces an alternating output having one of two directly opposite phases in accordance with the polarity of the D. C. potential existing across its input terminals. Circuitry generally shown at 102 serves to amplify the alternating output of the chopper 100. The output of amplifier 102 is in turn connected to a computer servomotor 104 which may be of the two phase type. The servomotor 104 may be geared to the movable arm 77a as shown by the heavy dotted line 106. In addition, it may be desirable to mechanically

couple a recording indicator 86 of the recorder 48 to the servomotor 104 to provide visual indication of the position of the tap 77a on the recorder slidewire.

The exemplary timing circuit of Fig. 4 is helpful in explaining the operation of the present invention and, in particular, the sequence of switching operations performed in the circuit of Fig. 3. The measured thickness variations are recorded on the moving chart and simultaneously averaged for the time T_1 required for one revolution of the die. The average thickness value is then presented for a time T_2 on the chart. This sequence can be repeated as often as necessary by means of an initiate switch 110. The aforesaid time periods are determined by timers 112, 114 that can be connected across a source or A. C. supply 117. The timers may be of the electromechanical type such as that manufactured by Microflex Corporation and sold under the name of "Eagle Timers". Timer 112 controls the time of integration and may be manually adjustable by means of a knob 113 to correspond to the speed of die rotation. As soon as switch 110 is depressed, timer 112 starts and locks itself on by means of its auxiliary contacts 112a. During this time, relay contacts 90c in Fig. 3 connect the chopper between the slidewire arms 72a and 77a to permit the marking indicator 86 to follow the output of the measuring servo 46. Contacts 90d ground the arm 75a of the target potentiometer to enable the integrator 54 to average the difference between the measured and the desired thickness values.

When the die 16 has made one revolution, timer 112 "times out" and contacts 112b energize timer 114 whose "on time" interval may be adjustable by means of a knob 115. In most cases the recorded average is presented for a period of time T_2 much less than the averaging time T_1. Timer 114 is locked on by contacts 114a. Contacts 90a and 90c in Fig. 3 open to disconnect the repeat slidewire from the integrator input and from the chopper input respectively. Contacts 90d open to lift the target arm 75a from ground. Contacts 90e and 90f close to couple the integrator output into the recorder bridge 70. Therefore, a line is drawn on the chart in accordance with the voltage appearing across the capacitor 96. When timer 114 times out, contacts 90b serve to reset the integrator 54, the initial switch states are established, and contacts 114b start the sequence again by energizing timer 112. It may be desirable to eliminate the automatic recycling feature and use only manual demand operation via the switch 110.

It is apparent that the techniques of the present invention may be applied with equal utility to plastics extruders in which the die is rotated through some angle less than 360 degrees and counterrotated through the same angle. For example, if an oscillatory motion of 180 degrees is used, a gauge may be mounted at each edge of the sheet to provide complete information of profile.

While a single rotation average over any 2π segment of the die 16 provides enough information for manual or automatic control of profile, it is highly desirable to correlate the measured and recorded points of profile with the controlling die section. Referring now to Figs. 5, 6 and 7, most of the blocks are the same except that a circular chart recorder 116 is used in preference to the strip chart recorder 48. Recorder 116 provides a circular record 118 with the die sections numbered thereon as shown. It is suggested herein to mount an actuating pin 120 on the rotating member 122 and a switch 124 on the stationary extruder periphery 126 to provide a pulse on line 128 once any die section, # 1 for example, passesthe switch 124. Since it takes a finite amount of time for the material to pass from the die to the point of profile measurement after the take-away rolls 25, a transport lag timer 130 delays the indexing information from the switch 124 to ensure that the chart record is properly registered with respect to the profile data being measured. If the line speed is constant a timer can be used at 130 and manually set for the transportation time; however, if line speed varies, a footage counter would be used. In this case, a unit 132 having a wheel 134 in tractive engagement with the sheet 24 would, through a cam switch arrangement, pulse over line 136 a counter in the timer 130. After a preset number of pulses, a suitable initiate signal is transmitted over line 138 to start the recording of profile information.

In the operation of this embodiment the profile information may be recorded as shown, starting with die section # 1. Before the information on all 16 die sections, for example, has been recorded, it may be desirable to draw a target line 140 on the chart 118 so that deviations of the sheet from the desired value at each die section are readily apparent to the operator. Modifications of the circuitry of Fig. 3 suitable for switching the target setter 142 into the recorder will be apparent to those skilled in the art. Having this information, the operator can proceed to manually adjust the die bolts of each section as indicated by the actuator elements 144—174. The die bolts alter the spacing 178 between the core 180 of the die and the surrounding die block 182. Different methods of die control such as a zone heating may be used but the application of the teachings of the present invention as described hereinabove to these devices should be apparent. In addition, certain other refinements such as automatic control of profile

will be obvious to those skilled in the art.

The advantages of the above described method and apparatus should now be apparent. By measuring at the edge one obtains a true profile. By averaging the profile over one die rotation a significant figure of extruder output thickness is obtained that is not the result of a complicated measurement. By correlating die position with the measuring and recording operation and by using a circular chart presentation on which the die sections are marked, a basis for control of the profile is readily obtained.

Although certain specific embodiments of the invention have been shown and described herein, many modifications may be made thereto without departing from the scope of the invention as set forth in the appended claims.

Attention is drawn under Section 8 of the Patents Act 1949 to Specification No. 1,054,989.

WHAT WE CLAIM IS:—

1. A method of measuring the thickness of a sheet during production by a tubular product forming device which distributes variations in thickness about the circumference of the tubular product, the tubular product then being flattened to form a moving sheet of double thickness, said method comprising the steps of measuring the thickness of the double sheet along one edge thereof and deriving from the measurements an indication of a single thickness across the sheet.

2. A method as claimed in Claim 1 including the step of recording the thickness measurements of the sheet to provide a single thickness profile record.

3. A method as claimed in Claim 1 or Claim 2 including the step of averaging the total thickness measurements and recording on a record the average values taken.

4. A method as claimed in Claim 1, 2 or 3 in which said variations take the form of a zone or zones which spiral about the circumference of the product and the thickness measurements are averaged over a time period sufficient to allow at least one entire circumference of said product to be measured.

5. A method as claimed in any one of the preceding claims in which said device includes a generally circular die having a plurality of adjustable peripheral die sections spaced therearound and a rotatable part causing said variations to spiral about the circumference of said tubular product and wherein the thickness measurements are made at a predetermined fixed operating position relative to, overlying, and immediately adjacent to one edge of the flattened double thickness sheet so that a double thickness measurement of the output of a single adjustable peripheral die section is obtainable and said measurements are utilised to adjust the peripheral die sections to maintain the single thickness of said sheet within predetermined limits.

6. A method as claimed in Claim 5 including deriving an indication of the sheet thickness produced by each adjustable die section in succession during rotation of the rotatable part.

7. A method as claimed in any one of the preceding claims including using a radioactive source and a detector for making the thickness measurements.

8. A method as claimed in Claim 1 in which said device includes a generally circular die having a plurality of adjustable peripheral die sections spaced therearound and a rotatable part to cause said variations to spiral about the circumference of said tubular product and including averaging the thickness measurements for a time period sufficient to allow at least one entire circumference of said product to be measured and utilising the average of the thickness measurements to adjust the tubular product forming device to obtain a predetermined sheet thickness.

9. A method of measuring the thickness of a sheet during production by a tubular product forming device substantially as described herein with reference to the accompanying drawings.

10. In apparatus for producing sheet material comprising a tubular product forming device which produces variations in thickness which are distributed about the circumference of the product and means for flattening the product to form a sheet of double thickness, a measuring system comprising means positioned at one edge of the sheet for measuring the total sheet thickness at said edge and means for deriving from said measurements an indication of the single thickness across said sheet.

11. A measuring system as claimed in Claim 10 including a recorder for recording the single thickness measurements made by said measuring means.

12. A measuring system as claimed in Claim 10 or Claim 11 including an averaging circuit for averaging the thickness measurements provided by said measuring means.

13. A measuring system as claimed in Claim 11 including an averaging circuit for averaging the thickness measurements provided by said measuring means, the averaged thickness measurements being recorded by said recorder.

14. In apparatus for producing sheet material comprising a tubular product forming device which produces variations in thickness in the circumference of the tubular product, the variations spiralling about the circumference of the product and means for flattening the product to produce a sheet of double thickness, a measuring system as

claimed in Claim 12 or Claim 13 in which the averaging circuit is arranged to average the thickness measurements made by the measuring means over a time period sufficient to allow at least one entire circumference of the product to be measured.

15. In apparatus for producing sheet material comprising a blow film extruder having a substantially circular die including a plurality of adjustable peripheral die sections spaced therearound and a rotatable part which causes variations in thickness of the tubular product produced by the extruder to spiral about the product, and means for flattening the product to produce a sheet of double thickness, a measuring system comprising a gauge positioned to measure the thickness of one edge of the double sheet and means for deriving from the thickness measurements an indication of the single thickness across the sheet.

16. A measuring system as claimed in Claim 15 including an averaging circuit for averaging the thickness measurements made by said gauge over a time period sufficient to allow at least one entire circumference of the product to be measured.

17. A measuring system as claimed in Claim 16 including a recorder for recording the average and instantaneous values of thickness as measured by said gauge, a timer and a control circuit connected thereto to control alternate application to the recorder of the instantaneous and average thickness measurements.

18. A measuring system as claimed in Claim 15, 16 or 17 including means responsive to the thickness measurements made by said gauge to control the adjustment of the peripheral die sections to maintain the thickness of the sheet within predetermined limits.

19. A measuring system as claimed in Claim 18, including means for adjusting each die section as the gauge measures the double thickness of the sheet produced by that die section.

20. A measuring system as claimed in any one of Claims 15 to 19 including means for maintaining constant the position of the gauge relative to the sheet.

21. A measuring system as claimed in any one of Claims 10 to 20 in which said measuring means or said gauge comprises a radiation gauge.

22. A measuring system as claimed in Claim 21 in which said radiation gauge includes a radioactive source for positioning on one side of said sheet and a detector for positioning on that side of said sheet opposite to said one side, the position of the source relative to the sheet being such that all the radiation from said source is directed at said sheet.

23. In apparatus for producing plastic sheet material comprising a tubular product forming device including an extruder having a generally circular die comprising a plurality of adjustable die sections spaced therearound, means in said circular die for receiving raw plastics material at an adjustable rate under pressure and extruding a continuous generally tubular length of said plastics material, means for blowing air through said circular die to expand said tubular length of plastics material into a bubble, means for rotating at least one component of said extruder to distribute thickness variations in said plastics material about the circumference of the tubular length thereof, and means for flattening said bubble of plastic material into a sheet of double thickness, the output of each adjustable die section forming a longitudinally extending spiralling zone with each zone overlapping itself at the edges of the flattened sheet to form individual double thickness areas which pass a predetermined fixed position adjacent one edge of the sheet as the sheet is extruded, a measuring system as claimed in Claim 11 in which said measuring means includes a gauge overlying said predetermined fixed position and immediately adjacent said one edge of said flattened double thickness sheet for measuring the double thickness dimension thereof and means for averaging the output of said gauge for a time period sufficient to include the thickness variations produced over at least one rotation of the rotating means and in which said deriving means includes means for displaying said average value of the thickness dimension of said double thickness sheet at said edge as an indication of the average value of the single thickness profile of said sheet to enable adjustments to be made in the average sheet thickness produced by said extruder.

24. A plastic sheet producing apparatus comprising a blown film extruder for producing a bubble of plastics material having variations in thickness which spiral around the bubble circumference, means for drawing off the bubble and flattening it to produce a sheet of double thickness, a gauge positioned downstream of the extruder and flattening means for measuring the double thickness of the sheet at one edge thereof and means for deriving from the measurements made by said gauge an indication of the single thickness across said sheet.

25. Apparatus as claimed in Claim 24 in which said extruder includes a generally circular die having a plurality of adjustable die sections spaced therearound and a rotatable part which causes said variations to spiral about the bubble circumference.

26. Apparatus as claimed in Claim 25 including control means responsive to the measurements made by said gauge to adjust said die sections to maintain the thickness of said sheet within predetermined limits.

27. Apparatus as claimed in Claim 26 in which said gauge is arranged to measure the double thickness of the sheet produced by each die section and said control means is arranged to adjust each die section as a portion of the sheet produced by that section is being measured by the gauge to maintain the thickness of the sheet within predetermined limits.

28. Apparatus as claimed in any one of Claims 24 to 27 including an average computer for averaging the thickness measurements made by said gauge over a time period sufficient to allow at least one entire circumference of said bubble to be measured and a recorder for recording the average values of said measurements.

29. Apparatus as claimed in any one of Claims 24 to 28 including means for visually displaying the thickness measurements made by said gauge.

30. Apparatus as claimed in any one of Claims 24 to 29 in which said gauge includes a radioactive source for positioning on one side of said sheet and a detector for positioning on that side of said sheet opposite to said one side, the position of the source relative such that all the radiation from said source is directed at said sheet.

31. A measuring system substantially as described herein with reference to Figures 1, 2, 3 and 4 of the accompanying drawings.

32. A measuring system substantially as described herein with reference to Figures 5, 6 and 7 of the accompanying drawings.

33. A plastics extrusion process substantially as described herein with reference to Figures 1, 2, 3 and 4 of the accompanying drawings.

34. A plastics extrusion process substantially as described herein with reference to Figures 5, 6 and 7 of the accompanying drawings.

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Printed for Her Majesty's Stationery Office by Burgess & Son (Abingdon), Ltd.—1970.
Published at The Patent Office, 25 Southampton Buildings, London, W.C.2,
from which copies may be obtained.

FIG. 1.

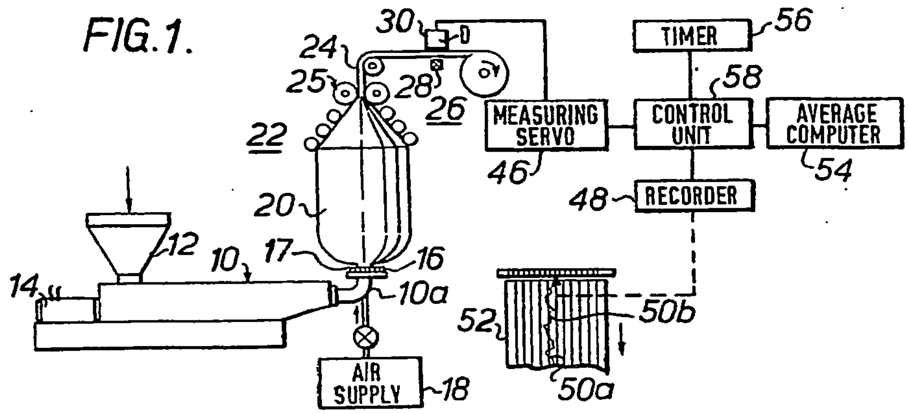


FIG. 2.

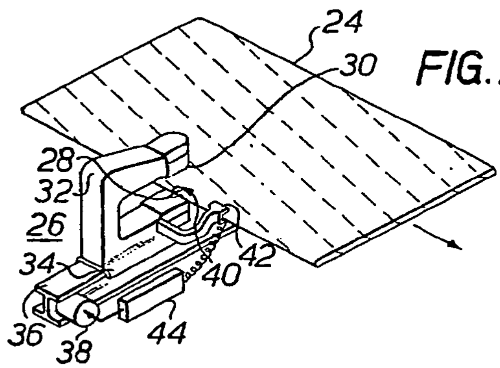


FIG. 4.

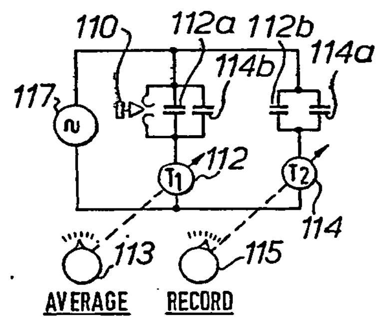


FIG. 6.

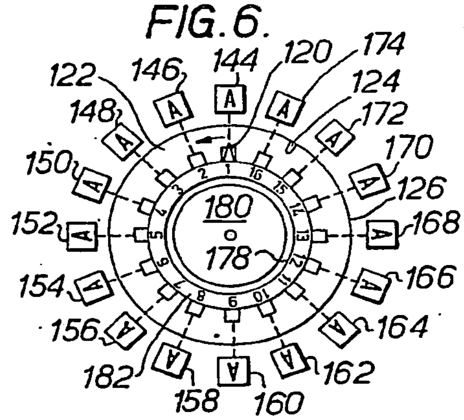


FIG. 7.

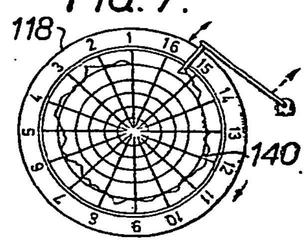


FIG. 3.

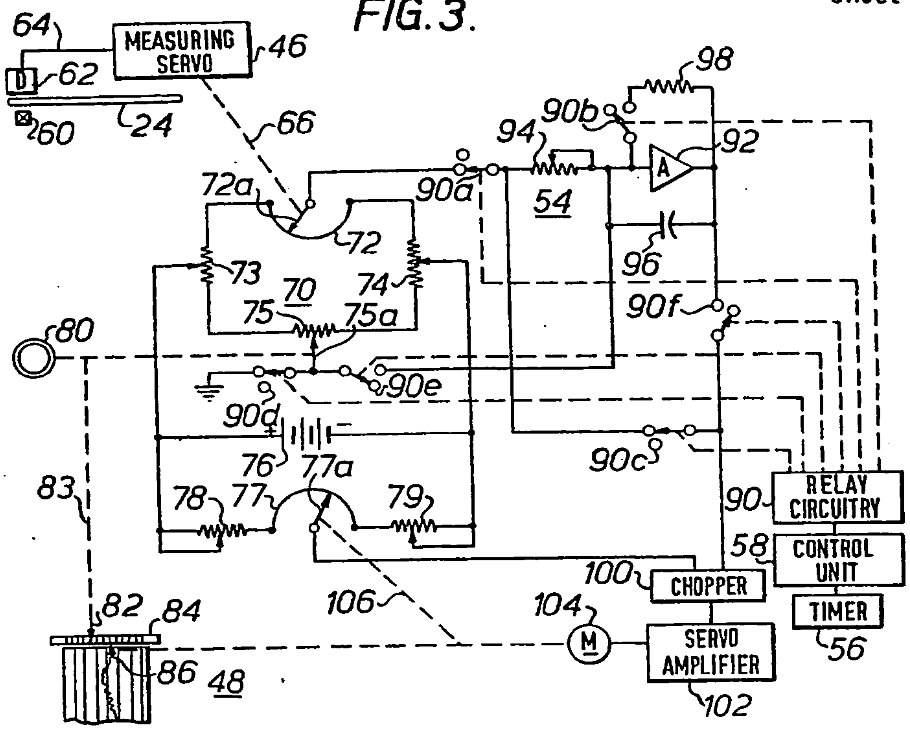
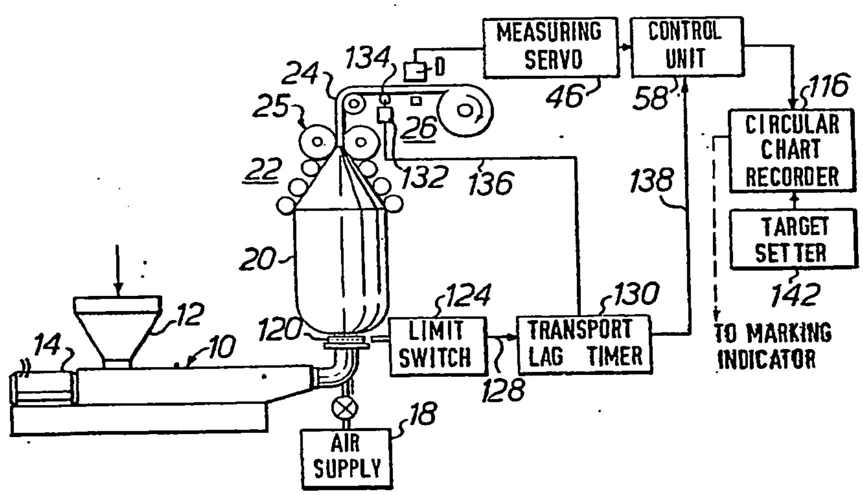

MEASURING SERVO
RELAY CIRCUITRY
CONTROL UNIT
TIMER
CHOPPER
SERVO AMPLIFIER
A
M

FIG. 5.


MEASURING SERVO
CONTROL UNIT
CIRCULAR CHART RECORDER
TARGET SETTER
TO MARKING INDICATOR
LIMIT SWITCH
TRANSPORT LAG TIMER
AIR SUPPLY